Victor Electronics Ltd.

Victor F47 120V-750VA VSC

Voltage Sag Compensator

User Manual

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1. Introduction

AC operated electronic equipment are vulnerable to **momentary losses of AC voltage**, which are known as **voltage sags**. Voltage sags are commonly caused by lightning, accidental short circuit, loose connection, starting of large motors (or air-conditioners) or abnormal use of the AC mains. In **sensitive and critical applications**, such as semiconductor material processing and medical operation, voltage sags may result in **serious problems**. In order to tackle this problem, the Semiconductor Equipment and Materials International (SEMI) defined, in **1996**, a **voltage sag immunity standard**, known as **SEMI F47-0200**, for semiconductor processing equipment manufacturers to conform to. Equipment compliant to this standard must have the specified immunity characteristics against voltage sags without the use of batteries. Based on the experience learned, the standard was redefined, in **2006**, as **SEMI F47-0706**. It is expected that new semiconductor processing equipment will be designed to be compliant to the new standard. It is also likely that the SEMI F47-0706 requirement will be extended to other application areas.

Victor's F47 Series of Voltage Sag Compensators have been developed jointly by **Victor Electronics** and **The Hong Kong Polytechnic University** to provide **sine-wave** AC backup power to enable electronic equipment to meet the **SEMI F47-0706** standard and to **tolerate 100%** momentary **loss** of AC mains voltage (**or** momentary **open circuit** in the AC line).

It should be noted that, although uninterruptible power supplies (**UPS**) can be used to solve voltage sag problems in computers, it is **not** a **suitable** solution **for many applications** due to the following reasons:

(1) A **battery** has to be used in a UPS. The acid, lead and other particles from a battery can be **harmful to the operating environment**.

(2) The **maintenance** of the battery being used and the disposal of used batteries can introduce **problems**.

(3) The output of a low-cost **UPS** is **often** a **rectangular-wave** voltage (instead of a sine-wave voltage). This is undesirable for many applications.

(4) There are often inductive loads in the electronic equipment. Normally a **low-cost UPS** would **not allow inductive loads**.

(5) The **slow transfer** time of low-cost UPS may cause sensitive relays or contactors to **chatter**.

In areas where **UPS** or **batteries** are **not acceptable**, **Voltage Sag Compensators can be used** to minimize the undesirable effects of voltage sags.

2. Principle of Operation

Fig. 1 shows a simplified schematic diagram of the Victor F47 Voltage Sag Compensator.

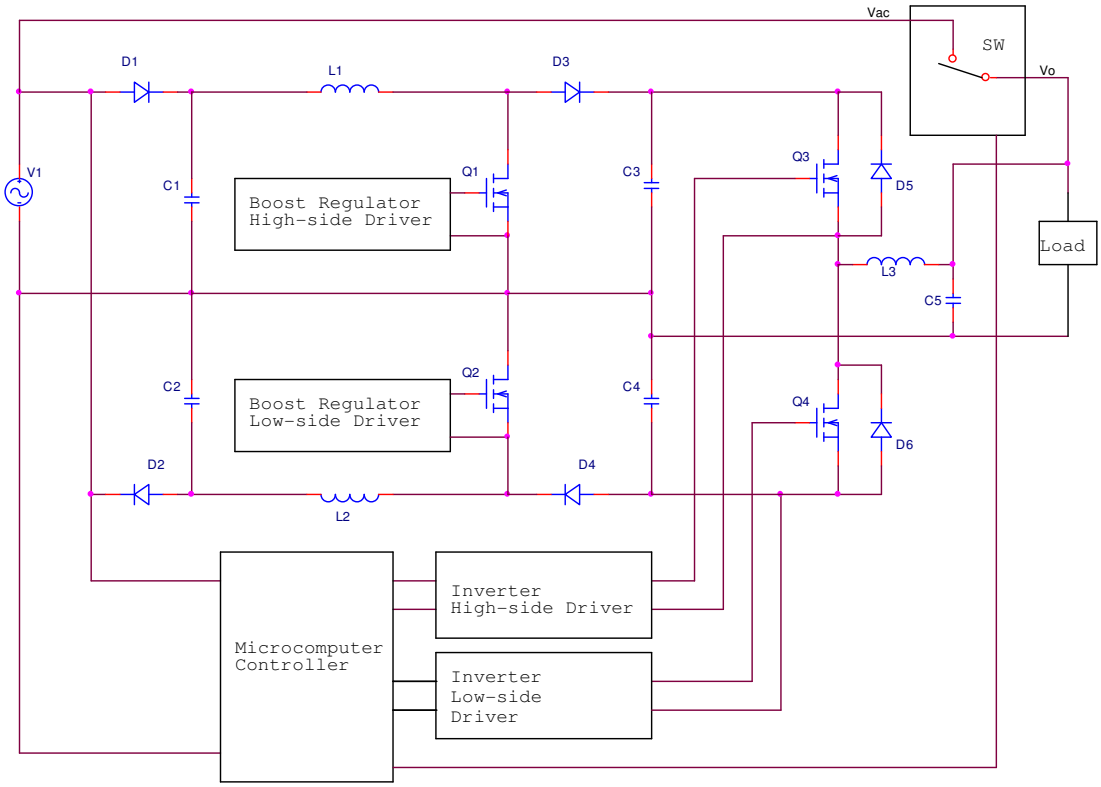

Fig.1 Simplified schematic diagram of Victor F47 Sag Compensator

In Fig. 1, D1 and C1 form a rectifier to provide positive power supply to the positive boost regulator composed of L1, Q1, D3, and C3. D2 and C2 form a rectifier to provide negative power supply to the negative boost regulator composed of L2, Q2, D4, and C4. Q3, Q4, D5, D6, L3, and C5 (together with the related drivers) form a DC to AC inverter. The Microcomputer Controller monitors the AC mains and controls the operation of the DC to AC inverter.

During **normal operation** the **AC mains is connected to the load** through the relay switch SW. The Inverter High-side and Low-side Drivers of the DC to AC inverter are disabled, so that the inverter output transistors Q3 and Q4 are turned off.

When a **voltage sag** in the AC mains is **detected** by the Microcomputer Controller, the relay switch SW is opened. The DC to AC **Inverter** is then

enabled to **generate a back up AC voltage (sine-wave)** for a preset period of time (adjustable from 0.25s to 2s). Within this period, the **Inverter provides sine-wave AC power** to the load.

At the **end** of the preset period (nominally preset to 2s), the inverter is disabled and the microcomputer switches the **load back to the AC mains**.

In Victor F47 Voltage Sag Compensators, the following **new technologies** have been developed to minimize the adverse effects of voltage sags:

(1) The technology of **storing up energy** in large capacitors and, when there is a sag in the AC mains, **converting most of the stored energy to AC back-up power**.

(2) The technology of using a microcomputer controller to **fast detect** the occurrence of **voltage sag** and to **control** the operation of the DC to AC (**sine-wave**) **inverter.**

(3) The technology of **fast switching** the **load** between the **AC mains** and the DC to AC **inverter,** while maintaining practically **zero conduction loss** during normal operation.

(4) The technology of **minimizing the chattering** of AC relays/contactors in the loading circuit using **software techniques**.

It should be noted that a very important task of the sag compensator is to ensure that the operation of AC relays/contactors in the loading circuit will not be affected by the transfer operation between the AC mains and the DC to AC inverter during the voltage sag period. It is well known that the transfer operation often results in chattering of contacts. Chattering can be minimized by reducing the transfer time. However, our study indicates that if the software that drives the AC to DC inverter is designed properly the relay/contactor can tolerable a much slower transfer time without chattering. In other words, chattering can be efficiently minimized by software.

In order to design proper software to reduce the chance of chattering, it is necessary to understand the dynamic behavior of relays/contactors. However such behaviors of AC relays/contactors under transient conditions (during the

transfer operation) are difficult to analyze because of the following reasons:

(1) In order to ensure that the energized solenoid will not drop out during the zero-crossing region of the AC driving current, the solenoid of an AC relay/contactor is split into two halves. On half of it has effectively a one-turn short-circuit secondary winding. This makes the analysis of the transient behaviors of AC relays/contactors complex.

(2) The energizing coil of AC relay/contactor is inductive and the exact current waveform of the effective energizing current of the solenoid under transient condition is difficult to determine.

In the design of the voltage sag compensator, extensive computer simulations have been used in Victor Electronics to analyze the behaviors of AC relays/contactors and to tailor-make software to minimize chattering during transfer periods.

3. Technical Specifications (typical)

Nominal AC Input Voltage: 120V

Maximum AC Input Voltage: 132V

Input Frequency: 50/60 Hz, auto-sensing

Output Capacity: 750VA

Voltage Drop due to Compensator (full load) : < 0.5V

Efficiency: 99% at full load (under no voltage sag condition)

Full Load Current:
6.25A (The load can be **resistive, capacitive, or inductive**.)

Inrush Current: 50A

Ride-through Time:

(1) Exceeds the **SEMI F47-0706** standard, which is shown in Table 1.

Sag depth*	**Duration at 50Hz**	**Duration at 60Hz**	**Time**
50%	10 cycles	12 cycles	0.2 second
70%	25 cycles	30 cycles	0.5 second
80%	50 cycles	60 cycles	1 second

Table 1 SEMI F47-0706 Standard

***Sag depth is expressed in percent of remaining nominal voltage. For example, a sag depth of 80% for 120V AC means that the voltage is reduced to 96V.

(2) Even under the condition of **zero AC input voltage** or **open-circuited input**, meets the ride-through time requirement of **one second** minimum at full load with load power factor of 0.25.

Voltage Sag Compensation Response Time:
4 milliseconds **(including detection time)**

Sag Compensation Threshold Voltage:
Adjustable from 85V to 115V in steps of 5V; factory preset to 100V. (See Paragraph 6 for details.)

Sag Compensation Time:
Adjustable from 0.25s to 2s in steps of 0.25s; factory preset to 2s. (See Paragraph 6 for details.)

Waveform of Output Voltage:
Sine-wave, with Total Harmonic Distortion < 8%

Fail Safe Mode:
The unit will not drop the load in the event the DC to AC inverter in the unit fails.

Recharge Time (for the energy storage capacitors to charge up again): 3 seconds

Indicators:
AC Mains Input (**green**), Compensator AC Output (**amber**), and Inverter Output (**red**)

Output voltage variation (for the **range of Operating AC Input Voltage from 105V to 125V** and load variation from **no load to full load**): 105V to 125V

4. Protection against Abnormal Operation

Under abnormal operating conditions, the DC to AC inverter in the Sag Compensator may be repetitively started to compensate the AC mains voltage. A typical example of abnormal condition is that the AC mains voltage is consistently below the threshold compensation level. Under such condition, the Sag Compensator will initially compensate the AC mains voltage for 2 seconds and then reconnect the load to the AC mains for 3 seconds. If the AC mains voltage is then still below the threshold compensation level, the compensator will begin another cycle of “2-second compensation followed by 3-second back to the AC mains”. However, if the repetitive rate of the compensation cycle is more than 4 times in every minute, the Sag Compensator may enter a protective mode operation. Under this mode of operation, the sag compensator will stop the compensation operation for 2 minutes, waiting the heat-generating components in the Sag Compensator to cool down. Within this 2-minute period, the load will be connected to the AC mains without compensation. At the end of the 2-minute period, the sag compensator will start another round of effort to compensate the AC mains voltage, as mentioned above.

The Sag Compensator can stay in the protective mode of operation indefinitely without damage.

As a further protective measure, it is recommended that a circuit breaker be used with the Compensator for protection against overloading. The current rating of the circuit breaker should be about 150% of the maximum current rating of the sag Compensator.

5. Simplified Test Procedure

In order to fully test the performance of the Voltage Sag Compensator, a programmable AC source (with galvanic isolation from the AC mains), an oscilloscope, and a programmable load are required. However, even **without** such **sophisticated equipment**, a **simplified functional test** can still be performed through the following procedures:

(1) Under power-off condition, connect the AC mains (**120V**) through an external ON/OFF switch to the Sag Compensator, which is shown in Fig. 2, where

G is the Ground terminal
L is the Live terminal
N is the Neutral terminal

Do not confuse the **live** line (**L**) with the **neutral** line (**N**) from the AC mains. For simple testing, it is not necessary to connect any load to the output terminal of the Compensator. **Keep the ON/OFF switch** in the **OFF** position initially.

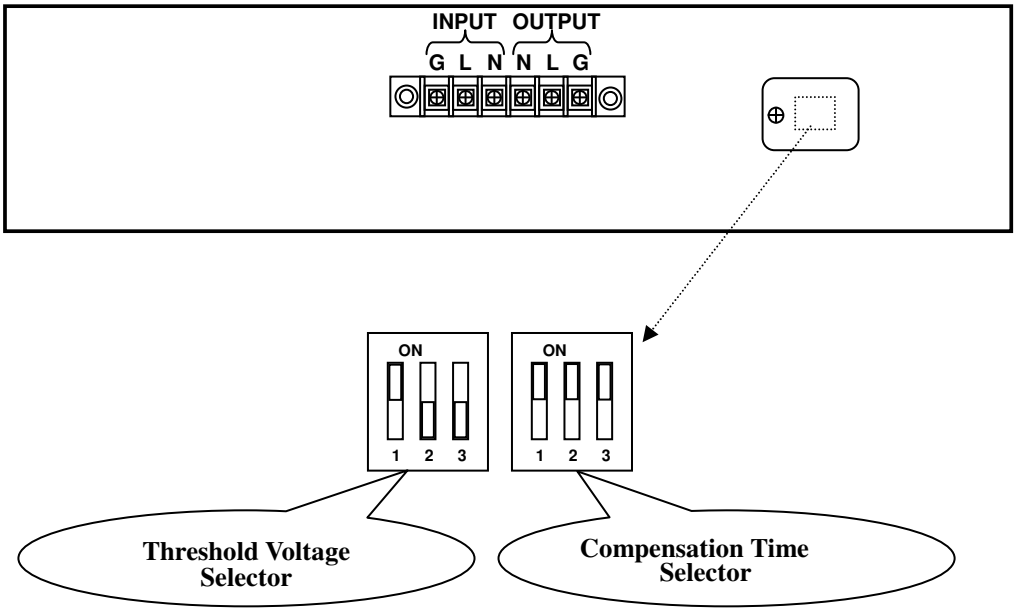

Fig. 2 Rear panel of Sag Compensator

(2) After checking the circuit, **turn** the ON/OFF **switch** to the **ON** position. The **green "AC Mains Input"** indicator and the **amber "Compensator AC Output"** indicator on the front panel of the Sag Compensator, as shown in

Fig. 3, will then **be lit up**.

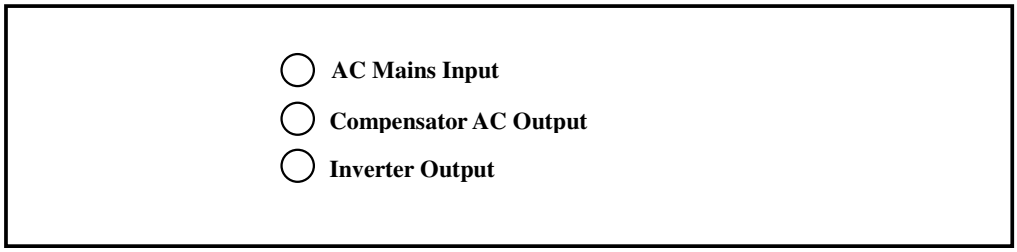

Fig. 3 Front panel of Sag Compensator

(3) **Wait for 10 seconds** to allow the Microcomputer Controller in the Sag Compensator to complete its initiation process.

(4) Manually **simulate a one-second complete AC mains power failure** by turning the ON/OFF switch to the **OFF** position for about **one second**, and then returning it back to the **on** position **again**. Check that the **amber "Compensator AC Output" indicator** remains **lit up without interruption**, indicating that there is no interruption in the AC output voltage. Also check that the **red "Inverter Output" indicator** is **lit up for two seconds** (assuming that the compensation time is preset to 2s), indicating that the Inverter has worked for two seconds to compensate for the voltage sag.

(5) After a voltage sag simulation, as described in (4), it is necessary to **wait for 3 seconds** after the Inverter has stopped operation (as indicated by the extinguished red "Inverter Output" indicator) to allow the energy-storage capacitors to charge up again, **before** performing the **next sag simulation**.

The above-mentioned test procedure is for the purpose of **testing the functionality** of the Sag Compensator only. If an **oscilloscope** is to be used to observe the output waveform of the Compensator, an **isolation transformer** should be used to provide galvanic insulation between the AC mains and the Sag Compensator.

Warning: The **high voltage** on the energy-storage capacitors in the Compensator may take up to **1 hour to discharge** to a safe value.

6. Threshold Voltage and Compensation Time Adjustments

The Sag Compensation Threshold Voltage of the Voltage Sag Compensator can be adjusted from 85Vac to 115Vac in steps of 5Vac, as shown in Table 2. The factory **default setting is 100Vac** (ON-OFF-OFF).

The Sag Compensation Time of the Voltage Sag Compensator can be adjusted from 0.25sec to 2.00sec in steps of 0.25sec, as shown in Table 3. The factory **default setting is 2.00 sec** (ON-ON-ON).

Warning: Turn off the power when changing the positions of the selector switches.

Threshold Voltage Selector (SW1)			
V_{TH}	SW1_1	SW1_2	SW1_3
115Vac	ON	ON	ON
110Vac	ON	ON	OFF
105Vac	ON	OFF	ON
*100Vac	ON	OFF	OFF
95Vac	OFF	ON	ON
90Vac	OFF	ON	OFF
85Vac	OFF	OFF	ON
100Vac	OFF	OFF	OFF

* Factory default setting

Table 2 Threshold Voltage Selector

Compensation Time Selector (SW2)			
T_{COMP}	SW2_1	SW2_2	SW2_3
*2.00s	ON	ON	ON
1.75s	ON	ON	OFF
1.50s	ON	OFF	ON
1.25s	ON	OFF	OFF
1.00s	OFF	ON	ON
0.75s	OFF	ON	OFF
0.50s	OFF	OFF	ON
0.25s	OFF	OFF	OFF

* Factory default setting

Table 3 Compensation Time Selector

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